The visibility distance of a smoke body having a mean diameter $D$ times that of the standard test smoke may be found by writing the visibility equation in the form

$$\frac{x}{d}\log 40+\log (1-B/R)-\log\left[1-f\left(\frac{x}{D}\right)\right]=0,$$

where $x$ is the visibility distance and $d$ the distance of photometric balance. A few solutions of this equation for $x$ (for dark backgrounds) with different values of $D$ are given in table 5.

TABLE 5

| $d$ (Distance of photometric balance in miles) | $x$ (Visibility distance in miles) | | | |
|---|---|---|---|---|
| | $D$=1 | $D$=4 | $D$=6 | $D$=8 |
| 8 | 8.6 | 13.2 | 14.8 | 15.8 |
| 12 | 11.5 | 16.2 | 19.8 | 21.6 |
| 16 | 14.0 | 21.4 | 24.4 | 26.3 |

If a standard size of test smoke is observed through binoculars, $D$ becomes the magnification (in diameters) of the binoculars.

It can be shown that the small test smoke might be visible at a distance of 65 or 70 miles if the transmission factor were 100 percent. However, this can never happen, because even on the clearest days each mile of the lower atmosphere absorbs and scatters 3 or 4 percent of the light traveling through it. Thus, the haze resulting from this scattering, as well as the decrease in the smoke's actual brightness, causes a tremendous loss in visibility distance, even under the most favorable conditions.

CONCLUSIONS

1. Small smoke columns can be seen farther when the observer is looking into a low sun than when the observer has the sun at his back. Trees, houses, and similar objects cannot be seen as far toward a low sun as they can away from the sun.

2. The locus of the position of a smoke column in sunlight at the maximum distance of visibility from an observation point is approximately a circle. The observation point is displaced from the center for light backgrounds, but moves nearer the center for dark backgrounds. The radii of such curves increase as the brightness of the background decreases.

3. The visibility distance does not change greatly with intrinsic background brightness in the direction of a low sun, because the haze in that direction is always many times brighter than any natural background.

4. From indirect measurements and theoretical considerations it appears that smoke columns can be seen farther on cloudy days than on clear days, the difference being much greater against light backgrounds than against dark backgrounds. Opaque objects such as trees cannot be seen as far on cloudy days as on cloudless days.

5. For all practical considerations, the safe visibility distance of smoke columns in shadows appears to be zero in the direction of a low sun.

6. Small changes in the size of a smoke body do not cause appreciable changes in its visibility distance.

7. In very clear weather small changes in atmospheric conditions will result in large changes in visibility distance.

# DESTRUCTIVE EASTERLY GALES IN THE COLUMBIA RIVER GORGE, DECEMBER 1935

By D. C. CAMERON and ARCHER B. CARPENTER

[Weather Bureau, Portland, Oreg., August 1936]

Several times each winter the easterly winds in the Columbia River Gorge reach gale force, and continue at that velocity for a week or 10 days, and in some instances for nearly a month (1) (2). In December 1935 the easterly winds reached such a force that all wind instruments at Crown Point, Oreg., were completely carried away.

This tremendous flow of air is a result of deepening of nocturnally cooled air collected over the Columbia and Snake River Basins, which, like the water in these rivers, finds its way out through the Columbia River Gorge, a natural water-level route through the Cascade Range.

Any cessation of cyclonic activity in this large inland basin permits rapid cooling, by nocturnal radiation, of the polar Pacific air which normally is present. This cooling soon builds up a deep, cold layer, filled with low stratus clouds and fog; and the air flow westward through the gorge increases in proportion to the depth of the cold air (3) (4). Occasionally a small amount of transitional polar continental ($N_{PC}$) air which has spilled westward through the passes in the Rocky Mountains adds to this drainage. When this occurs a drop is noticed in the temperature and dew points in the gorge, and an increase is noted in the wind velocities. Such a combination of air drainage was sufficient on December 20, 1935, to cause considerable destruction at Crown Point, Oreg., and elsewhere in the western gorge area.

The ratio between the pressure gradient from Hood River to Portland, Oreg., and the easterly winds at Cascade locks and Crown Point is quite constant, as may be seen from figure 1. The top and bottom curves on the graph represent *easterly* wind velocities *above* the neutral lines, and *westerly* wind velocities *below*. The upper and lower curves are for Crown Point and Cascade locks, respectively. The center curve represents difference in pressure from Hood River to Portland, with plus values when the pressure gradient was directed from Hood River toward Portland, and minus values when the reverse occurred.

Pilots using this airway estimated wind velocities at 4,000 feet to be about 30 miles per hour when the surface velocities averaged about 50 miles per hour. The pilots did not fly in this air stream, as it was extremely turbulent; the estimate was based on the very rapid rate at which clouds, from the upper portion of the inland lake of cold air just below the inversion, were flowing westward over a 4,000-foot ridge. The pilots flying this route were amazed as they watched these clouds being carried violently into the gorge and dissipated. The top of the stratus clouds east of the Cascade Range was reported at a maximum of approximately 5,000 feet. This maximum was reached after the addition of the $N_{PC}$ air. The previous top was usually between 3,300 and 4,500 feet.

Lowering of the cold air top east of the Cascade Range was partly counteracted by radiation cooling at the top of the cloud layer in the cold air, and by radiation cooling on the mountain slopes rising above the lake of cold air. Small additions of $N_{PC}$ air coming westward through the passes in the Rocky Mountains temporarily increased the depth of the cold air, and increased the flow through the gorge.

A rough estimate of the magnitude of this flow may be made. The narrowest part of the gorge, near Cascade locks, has a cross section below 4,000 feet of about 4.1 square miles. Assuming an average velocity of 35 m. p. h. through this section, the discharge of air is 3,444 cubic miles per day.

This discharge would produce a lowering of approximately 73 feet per day over the 248,438 square miles east of the Cascade Range, drained by the Columbia and Snake Rivers. Volume has been used in the above estimates because the surface of the area exposed to radiation varies from nearly sea level to over 10,000 feet on some of the mountain slopes, making it difficult to arrive at anything more than a rough estimate. The magnitude of lowering necessary to counteract the additions of cold air is therefore conservative, since much of the radiation took place at elevations where the air was of less density than that which flowed out through the gorge.

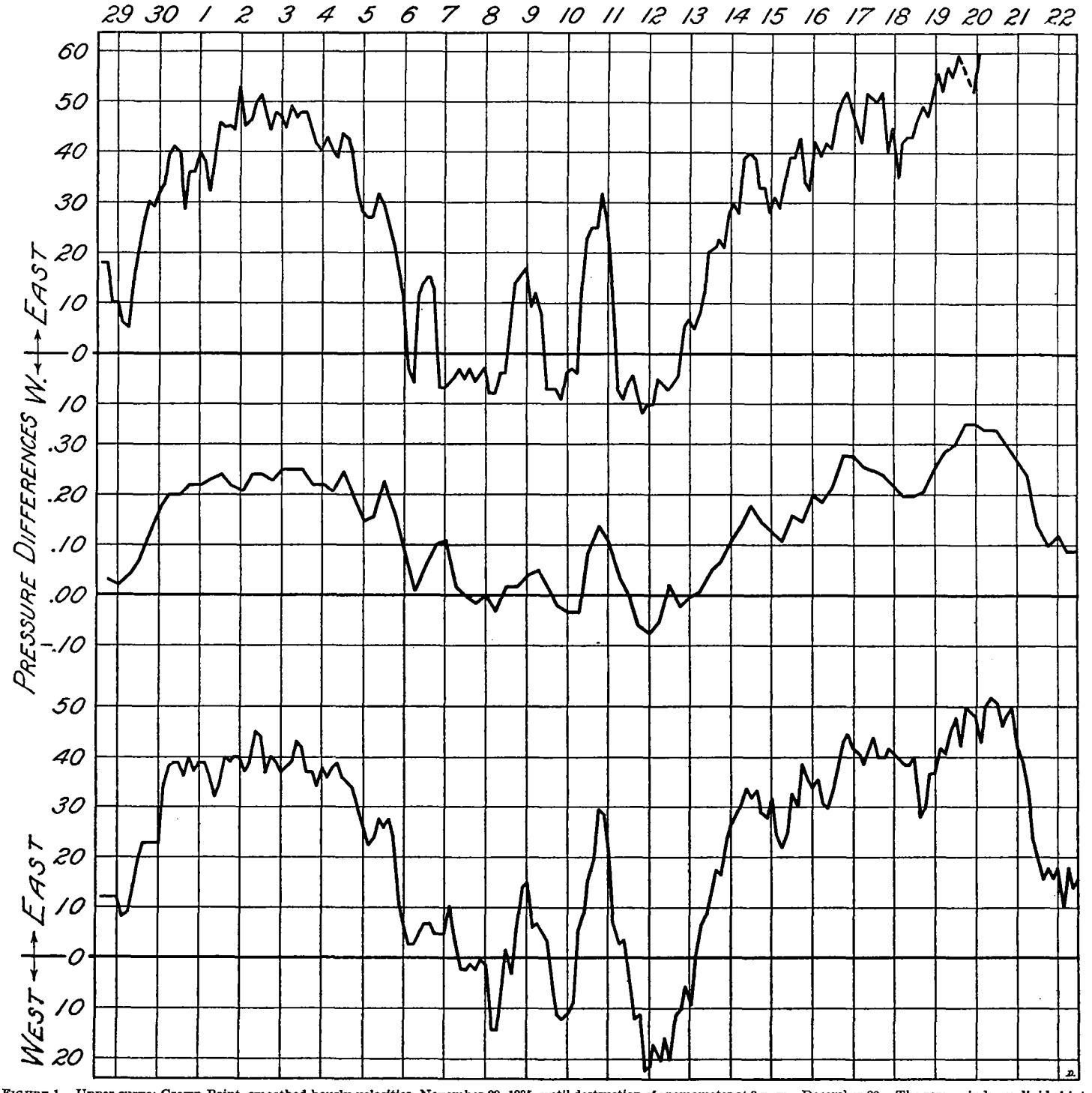


FIGURE 1.—Upper curve: Crown Point, smoothed hourly velocities, November 29, 1935, until destruction of anemometer at 3 p. m., December 20. The gorge winds are divided into easterly and westerly component values, the neutral line representing the shift in wind. Middle curve: Pressure differences, between Hood River and Portland, Oreg., distance 59 miles. Positive values represent higher pressure at Hood River, negative values lower. Lower curve: Cascade locks, smoothed hourly velocities, November 29, 1935, to December 22, inclusive. Winds divided into easterly and westerly component values, similar to Crown Point. Pressure difference in hundredths of inches. Wind velocities in miles per hour.

The temperatures at Crown Point were between 30° F. and 34° F., and the specific humidities were between 2.9 and 3.5 parts per thousand during the period of easterly wind used in the calculations above. The constancy of the temperatures and specific humidities would indicate cooling and air drainage in one type of air without air added from other sources. It is reasonable to assume that the drainage air was actually cooled 10° to 15° each night, since any air from the Pacific Ocean would be that much warmer than the drainage air. The temperatures in the inversion above the lake of cold air were 15° to 26° higher than in the cold air below. Any addition of cold air from the continent, westward through the passes in the Rocky Mountains, is immediately detected in the lower temperatures and specific humidities through the Columbia River Gorge.

On December 18, pilots reported that mountain peaks in the inversion appeared to be 500 or 600 feet higher than they actually were, due to mirage effects. Several inversions were noted in the warm air above the stratus and fog layer. An inversion of 26° F. was reported over Pendleton on December 18, with a temperature of 20° F. at 3,000 feet in the cloud layer, and 46° F. at 5,700 feet, just above the stratus cloud top.

Active subsidence in the upper air east of the Cascades is indicated by the inversions discovered by the pilots. Further evidence is found in the temperature structure in the air east of Portland. The surface temperature at Portland at 6 p. m. on December 19 was 36°, at 1,000 feet it was 33°, at 4,000 feet it was 39°, and at 5,000 feet it was 42° F. The above temperatures were taken by a pilot on the Portland-Pendleton airway, with the last reading approximately over Cascade locks. The free air temperatures near Portland in a northerly direction, at the same time, were 47° at 1,800 feet, 64° at 3,000 feet, and 57° F. at 4,000 feet. The warm air in the upper levels was a part of the subsidence flow from above the cold lake of air. The higher temperatures over the Portland area, as compared with the temperatures above the gorge, level for level, indicate spreading as the air left the gorge. The warm air aloft was thus brought to lower levels over Portland. A temperature of 70° F. was reported at 4,000 feet over Portland at 10 p. m. on December 20.

On December 19 the lake-level of the cold air was increased by addition of $N_{PC}$ air coming westward into the basin through the passes in the Rocky Mountains. This was both colder and drier than that formerly flowing through the gorge, and the pressure differences from Hood River to Portland were correspondingly increased as indicated on figure 1. The average hourly velocities reached a peak of 57 miles per hour at Crown Point, and 48 miles per hour at Cascade locks. Gusts of 79 miles per hour were measured at Crown Point before the power lines were carried away and made it impossible to use the wind indicator. A further increase in the wind and in the gusts on December 20 finally carried away the wind vane and the anemometer.

The position of the house at Crown Point in relation to the contour of the rocky promontory is such that the wind flow is decidedly upward from the steep east and northeast slope, the severe gusts having as much as a 45° upward component where they pass through the anemometer. An area of approximately 17 square feet of the overhanging eaves at the northeast corner of the house catches the full force of these extreme gusts, and this portion gave way. Other adjacent portions of the roof followed, exposing the loft of the house, and it was necessary to chop a hole in the southwest portion of the roof to release the tremendous pressure head which at times caused the building to belly out under the strain. The observer estimated hurricane gusts of as high as 120 miles per hour during the period of maximum destruction.

Shingles from the roof were scattered over an area one-quarter mile wide, and one-half mile long. This whole area was carefully searched for parts of the missing wind instruments. The only part found was one of the anemometer cups, and it appeared to have been torn from the cup arm by sheer inertial force. The cup was found about one-third mile from the station. A furniture truck, loaded with kitchen stoves and other furniture, and another truck with a trailer, were blown over. On the following morning, two closed cars lost their tops; this quickly resulted when a window was opened toward the wind. The wind pressure inside the cars was sufficient to instantly blow off the tops. Such was the force produced by the wind that the tops were observed to be carried up into the air and over the edge of the cliff without even touching the ground. No doubt this type of damage would have been greater except for the highway patrolmen, who only allowed persons with heavy cars and urgent business to pass along the highway.

Another interesting feature of this period was the extreme dryness of the soil and all vegetation, revealed on the 23d, when a thorough search of the entire area to the south and west of the station was made in quest of the missing wind vane and anemometer. Dust was stirred up in the grass and leaves at each step, as the loose topsoil, previously frozen, had been dried by the persistent, penetrating easterly gales.

The airway beacons were behaving erratically on the evening of December 20, and many reports were received that the lights were out, or were functioning peculiarly. Several of the beacons were visible from Crown Point during the night. One of them was pointed at an odd angle into the sky, and was discovered next morning to have been blown off its base, and to be lying on the small platform atop the tower. Other revolving beacons were noticed to be flashing mostly down the gorge. The airway mechanician, who was in the gorge during the night, said that the lights would turn partly into the wind, and a gust would force the beacon backward, then another attempt into the wind would occur, and the beacon would again be pushed back by the force of the wind. These revolving beacons are turned by a clutch, and the clutch was not powerful enough to turn the beacons against the extreme gusts. From the lower end of the gorge the beacons were visible most of the time as the wind kept them straightened out in nearly one direction.

The average velocity of 38.2 miles per hour at Crown Point, for the period included in this study, is the highest of record for such periods since the station was established in 1929. The highest average velocity for a previous period of easterly winds was 35 miles per hour for 10 days in December 1934. Easterly gales also occur in connection with the movements of cyclones and anticyclones, but they are usually of shorter duration, and the average velocities are somewhat less.

All barometric data from standard mercurial barometers, reduced to sea level.

Distances (air-line): Portland–Crown Point, 24 miles.
Portland–Cascade locks, 45 miles.
Portland–Hood River, 59 miles.

Elevations: Barometers above sea level: Portland, 39 feet.
Hood River, 393 feet.
Anemometer above ground: Crown Point, 24 feet.
Cascade locks, 55 feet.
Anemometer above river (sea level): Crown Point, 761 feet.
Cascade locks, 250 feet.

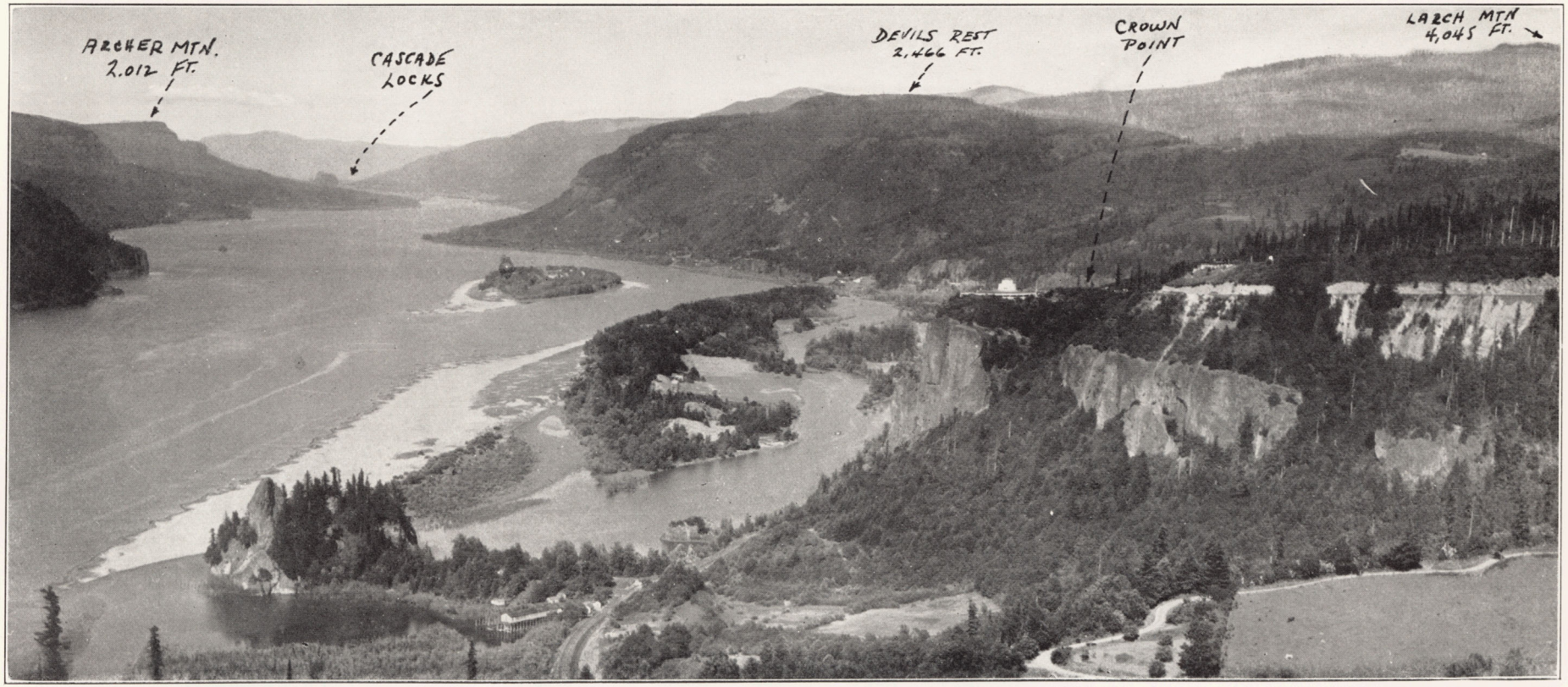


FIGURE 2.—Airplane view of Columbia River gorge, looking east-northeastward.

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# TROPICAL DISTURBANCES, AUGUST 1936


By WILLIS E. HURD

[Weather Bureau, Washington, September 1936]


Five tropical disturbances of the West Indian type occurred in the North Atlantic Ocean during August 1936. The earliest, that of the 9th–12th, which was of very slight intensity, was confined to the western Gulf of Mexico. The second, that of the 15th–19th, crossed the southern half of the Gulf, and locally developed some intensity during its westward passage. The third, that of the 20th–22d, originated east of the Bahamas, crossed northern Florida and thence, skirting the extreme northeastern Gulf coast, was of slight to moderate force only. The fourth disturbance, that of the 28th–30th, crossed the extreme lower portion of the Gulf, and was locally of considerable force on the 30th. Coincident with the final Gulf depression, reports were received on the 28th of a disturbance forming near 15° N., 45° W. This disturbance moved northwestward with rapid development. On the 31st, near 24° N., 56° W., winds of near hurricane force occurred. The storm thereafter moved into higher latitudes and on September 6–7 crossed the British Isles. A full description of this storm will appear in the September issue of the REVIEW.

Two tropical cyclones occurred off the west coast of Mexico this month. They are described on pp. 277–278.

The approximate tracks and positions of the centers of four disturbances are given in figure 1.

*Disturbance of August 9–12.*—The first definite signs of development of a cyclonic circulation, with light winds, appeared in the 7 p. m. ship reports of August 8 about 200 miles west-southwest of Port Eads. During the 9th the winds became somewhat more vigorous with forces of 4–5 (Beaufort scale), except that in one instance a moderate gale (force 7) from east occurred. This was radioed to the forecast centers by the S. S. *E. R. Kemp* (barometer 29.90) in 28.8° N., 92.1° W., and was the highest velocity reported during the life of the depression.

At 7 p. m. (e. s. t.) of the 9th the center of the disturbance was located near 28° N., 92° W., moving slowly in a westerly direction, accompanied by moderate to fresh winds. The center, with little apparent depression of the barometer, continued to move westward until the morning observation of the 10th, at which time it was located near 27½° N., 94° W. Thereafter, the course of the depression was south-southwest to southwest, unaccompanied by winds of known gale force, until, on the 12th, it entered the Mexican coast north of Tampico.

Beginning late on the 9th, and continuing until afternoon of the 12th, all interests were advised of the progress of the disturbance by advisories or bulletins issued at 6-hour intervals from the forecast center at New Orleans. Orders to hoist small craft warnings from Galveston to Corpus Christi were issued on August 10 at 3 a. m. (e. s. t.).

*Disturbance of August 15–19.*—This disturbance appears to have originated over the extreme northwestern part of the Caribbean Sea on the 14th, but available reports during the day showed only gentle winds and little depression of the barometer. On the 15th the disturbed condition had moved northwestward, and at 6 p. m. local time was centered in approximately 23° N., 88° W. A report received subsequently by mail showed that at this time the S. S. *Cauto*, Tampico to Baltimore, 23°40′ N., 88°35′ W., experienced a north wind, force 5, barometer 29.73; at 6.50 p. m. (local time) the wind, of same force, had hauled to east, pressure 29.56. At 8 p. m., with rising barometer, the ship reported a southeast gale, force 9, thereafter diminishing.

The northwestward movement of the disturbance continued until the morning of the 16th with no increase in intensity so far as reports indicate. The highest wind during the day, according to mail reports, was of force 8, ESE., during squalls experienced by the S. S. *San Benito*

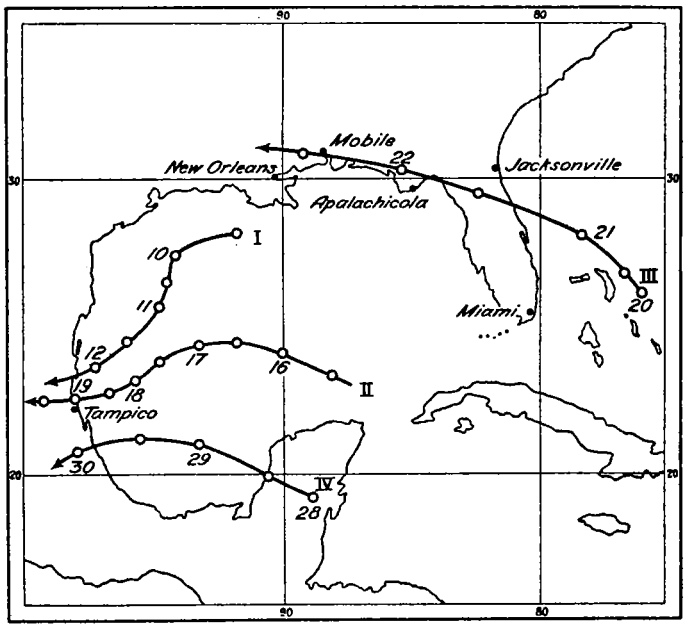


FIGURE 1.—Approximate tracks of tropical disturbances, August 1936.

between 4 and 7 a. m. (local time) near 24½° N., 90° W., lowest barometer 29.83.

The cyclone center, moving westward, was in approximately 24° N., 93° W., at 7 a. m. of the 17th, with winds of force 4–5 reported by ships at a considerable distance from the center. During the day the disturbance changed its course to southwesterly and at 7 p. m. (e. s. t.) was centered near 23½° N., 95° W. At this time the highest wind reported in connection with the disturbance was force 6, south, observed on the S. S. *Agwistar*, near 23° N., 94½° W.

The center continued to move southwestward until 7 a. m. of the 18th, at which time it was near 23° N., 96° W., and so far as reports indicate had meanwhile gathered energy. At this time the S. S. *San Ambrosia*, near